ATOM'S EMPIRICAL EVE: METHODOLOGICAL DISPUTES AND HOW TO EVALUATE THEM

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Scientists frequently disagree about what standards of proof or evidence to require for accepting a theory dealing with unobservables such as strings (in today's physics) or atoms (in the physics of 100 years ago). The paper concerns the latter, and examines why, on methodological grounds, atomic theory was so controversial among some prominent physicists and chemists even past the first decade of the 20 th century. It focuses on three figures: James Clerk Maxwell, who defended atomic physics; Friedrich Wilhelm Ostwald, who initially rejected it in the 1890's but changed his mind by 1908 as a result of experiments with cathode rays and Brownian motion; and Pierre Duhem, who vehemently rejected that theory until the day he died in 1916. Each of these scientists defended his position in the light of strongly held methodological views about what counts as empirical evidence or proof. I critically evaluate each of these views.

Maxwell in 1875 proposed what he called a "method of physical speculation," which is a compromise between competing methodological views expressed by Whewell and Mill. Like Whewell, appealing to "consilience" and "coherence," it requires that the theoretical hypotheses of atomic physics coherently explain and predict various types of observable phenomena. But it goes beyond Whewellian conditions, and requires the physicist to "deduce from the observed phenomena just as much information about the conditions and connections of the [atomic system] as these phenomena can furnish." Maxwell seems to have in mind causal-inductive arguments to the existence of atoms and their properties of a sort Mill demanded as the first of three steps in what he (Mill) called the "deductive method," viz. the inductive step to the existence of the entities postulated and the laws governing them. However, while Mill calls for such inductive arguments for each of the theoretical postulates, Maxwell does not. His line is that if you can supply arguments for some of these, and if you can show how the postulates introduced can furnish various explanations, you may have done enough to show that the postulates should be accepted. Maxwell proceeds to give such arguments for the molecular-kinetic theory, and claims to have thereby "justified the hypothesis that a gas consists of molecules in motion" subject to the kinds of dynamical assumptions he introduces.

Ostwald, Professor of Physical Chemistry at the University of Leipzig and 1909 winner of the Nobel prize in chemistry, prior to 1908 was one of the most important critics of atomism. In 1896 he published a paper entitled "Emancipation from Scientific Materialism," in which he spells out his objections to atomism and his defense of the "energetical" view, as he puts it. Ostwald offers three main objections. One is that mechanical theories, such as atomism is supposed to be, have not been altogether successful in other domains (in optical theory, he mentions problems with both wave and particle theories of light). Second, mechanical explanations allow reversibility of processes – something not observed generally in the physical world. Third, and most important from a methodological point of view, for Ostwald the aim of science is (as he puts it) to "coordinate measurable quantities," rather than to "picture" an underlying reality that we are unable to measure. In 1896 Ostwald was demanding that any entities introduced by a theory be measurable, and actually measured, in order for that theory to be empirically confirmed. In 1908, in the preface to the third edition of his textbook Outlines of General Chemistry, he claims to have been converted by experiments of J.J. Thomson, that measured the ratio of mass to charge of the electron, and of Jean Perrin, that measured Avogadro's number by experiments on Brownian motion. He considered his measurement requirement now satisfied, so that he could conclude that "the atomic hypothesis is thus raised to the position of a

scientifically well-founded theory."

Duhem, like Ostwald prior to 1908, rejected atomism on philosophical, physical, and historical grounds. For Duhem, writing in 1905, atomic theories are examples of theories about an unobservable material world underlying observable phenomena. Questions about such an underlying unobservable world, Duhem declared, "do not have their source in experimental method, which is acquainted only with sensible appearances and can discover nothing beyond them." For him, the aim of physical theory is not to discover realities underlying "sensible appearances," but to provide a highly abstract set of propositions that axiomatize and systematize laws that are themselves abstracted from "sensible appearances" and allow new such laws to be discovered. Duhem completely rejected atomic theory until he died in 1916, because it postulates the existence of entities which, in his view, are unobservable. Even the experiments of J.J. Thomson and Jean Perrin, of which he was aware, did not make electrons or atoms observable. Although these experiments produced (alleged) measurements of various "atomic" properties, the entities themselves remained unobservable ones postulated to explain observable phenomena such as fluorescence in the cathode tube and the Brownian motion of observable particles suspended in a liquid. Duhem also rejected the theory because it lacked the kind of logical systematization he sought.

In this paper, after setting out the scientific and methodological positions of the three scientists, I argue for the following theses:

The dispute involving the three scientists reflected differences over what objective methodological standards should be used in evaluating evidence for a theory postulating atoms and molecules. Contrary to what some might claim, these scientists did not propose their standards simply as personal choices among a set of legitimate ones.

Ostwald's measurement requirement and Duhem's observability requirement are much too strong to serve as necessary conditions of evidence or proof for postulated entities. Although these scientists do not attempt to justify their basic methodological demands, or at least do not succeed in doing so, in the paper I discuss what thoughts might lie behind their claims, and I offer criticisms of these while looking at the experiments of Thomson and Perrin, which converted Ostwald but not Duhem.

Maxwell's "method of physical speculation"- the Millian-Whewellian compromise- requires neither Ostwaldian measurements of the entity postulated, nor Duhemian direct observation. However, the method is too weak to conclude that the postulated entities exist, but, at best, that such a supposition is worth considering.